Environmental Studies in the Timmins Area

by

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1. Introduction

In April 1972, Ecstall Mining Company, a wholly-owned subsidiary of Texas Gulf Sulphur began operation of an electrolytic zinc plant (smelter and refinery) in the south-east corner of Hoyle Township, about 12 miles northeast of Timmins. The new plant has a capacity to produce annually, approximately 120,000 short tons of zinc metal, 230,000 tons of sulphuric acid, and one million pounds of cadmium metal. The Company reports that since April 1972 the plant has operated at between 70 and 90% of the theoretical rate. They also state that the operating rate will advance fairly steadily over the next eighteen months to between 130 and 140% of the theoretical capacity.

Because of the possible adverse affects to the environment, associated with such a concern, the Phytotoxicology Section of the Air Management Branch initiated a pre-pollution background investigation as to the state of the vegetation in the 1970 growing season, two years prior to the expected commencement of operations at the refinery.

The refinery was constructed adjacent to the ore concentrator which began operation in November 1966 and has been producing two grades of zinc concentrate and one grade of lead concentrate since that date. Cadmium is a secondary constituent of these concentrates. Following production, the concentrates are stored in open railroad cars, prior to shipment by rail to distant points for further processing.

This report outlines the data available to date, and discusses the impact on the environment of this industrial complex in the Timmins area.

Plot Establishment

During the growing season of 1970, ten surveillance plots and two controls plots (50 miles from the potential source) were established by Phytotoxicology personnel in the Timmins area (see map, page 4).

Plot #1 Location: 1 mile northeast of Hoyle on the south side of Highway #101 just west of the junction with Highway #610 in Matheson Township.

Site Description: Trembling aspen woods with mature to overmature aspen dominant, thinning out naturally with a heavy understory of mountain maple.

Plot #2 Location: 2 miles northeast of Hoyle on the east side of Highway #610 in Matheson Township.

Site Description: Open aspen stand on the edge of a black spruce woods. Trembling aspen is the dominant species with a speckled alder understory, and light ground cover. The soil is shallow, rocky and acidic.

Plot #3 Location: 5 miles northeast of Hoyle on the south side of Highway #610 just east of Matheson Creek in Matheson Township.

Site Description: Open aspen woods with a mixture of trembling aspen, balsam poplar, and speckled alder with a dense ground cover.

Plot #4 Location: 10 miles northeast of Hoyle on the east side of Highway #67 just north of the junction with Highway #610 in Dundonald Township.

Site Description: Open aspen woodlot with trembling aspen dominant and an understory of alder and hazel.

Plot #5 Location: 20 miles northeast of Hoyle,north of Highway #67 on the west side of Genest Rd. in Calvert Township.

Site Description: Dense stand of trembling aspen and speckled alder on a thin, damp, rocky, soil.

Plot #6 Location: 5 miles east of Hoyle on the north side of Highway #101 just east of the Frederick House River in Matheson Township.

Site Description: Trembling aspen dominant with a few scattered balsam fir and a ground cover of beaked hazel, mountain maple, with a few scattered speckled alder and pin cherry.

Plot #7 Location: 10 miles east of Hoyle in Kettle Lakes Provincial Park in German Township.

Site Description: Open, dry, sandy jack pine woods with an aspen-alder mixture.

Plot #8 Location: 20 miles east of Hoyle on the south side of Highway #101, approximately 1.5 miles east of Shillington in Currie Township.

Site Description: Mixed aspen and coniferous woods with many seedlings and saplings and an understory mostly of choke cherry.

Plot #9 Location: 10 miles southwest of Hoyle on the south side of Highway #101 just east of Schumacher in Tisdale Township.

Site Description: Open aspen stand on a rocky slope with a speckled alder and balsam fir understory.

Plot #10 Location: 20 miles southwest of Hoyle on the north side of Highway #101 near the township line between Ogden and Bristol Townships.

Site Description: Damp woods with trembling aspen dominant and mixed with conifers. The main understory species are speckled alder, mountain maple, viburnum and showy mountain ash.

Plot #11 Location: 50 miles southwest of Hoyle on the east side of Highway #144 in Stetham Township.

Site Description: Trembling aspen woods on a fine, sandy soil with a beaked hazel and mountain maple understory.

Plot #12 Location: 50 miles east of Hoyle on the south side of Highway #101 in Michaud Township.

Site Description: Mixed aspen, spruce and jack pine woods with an alder understory on a well-drained to dry, sandy soil.

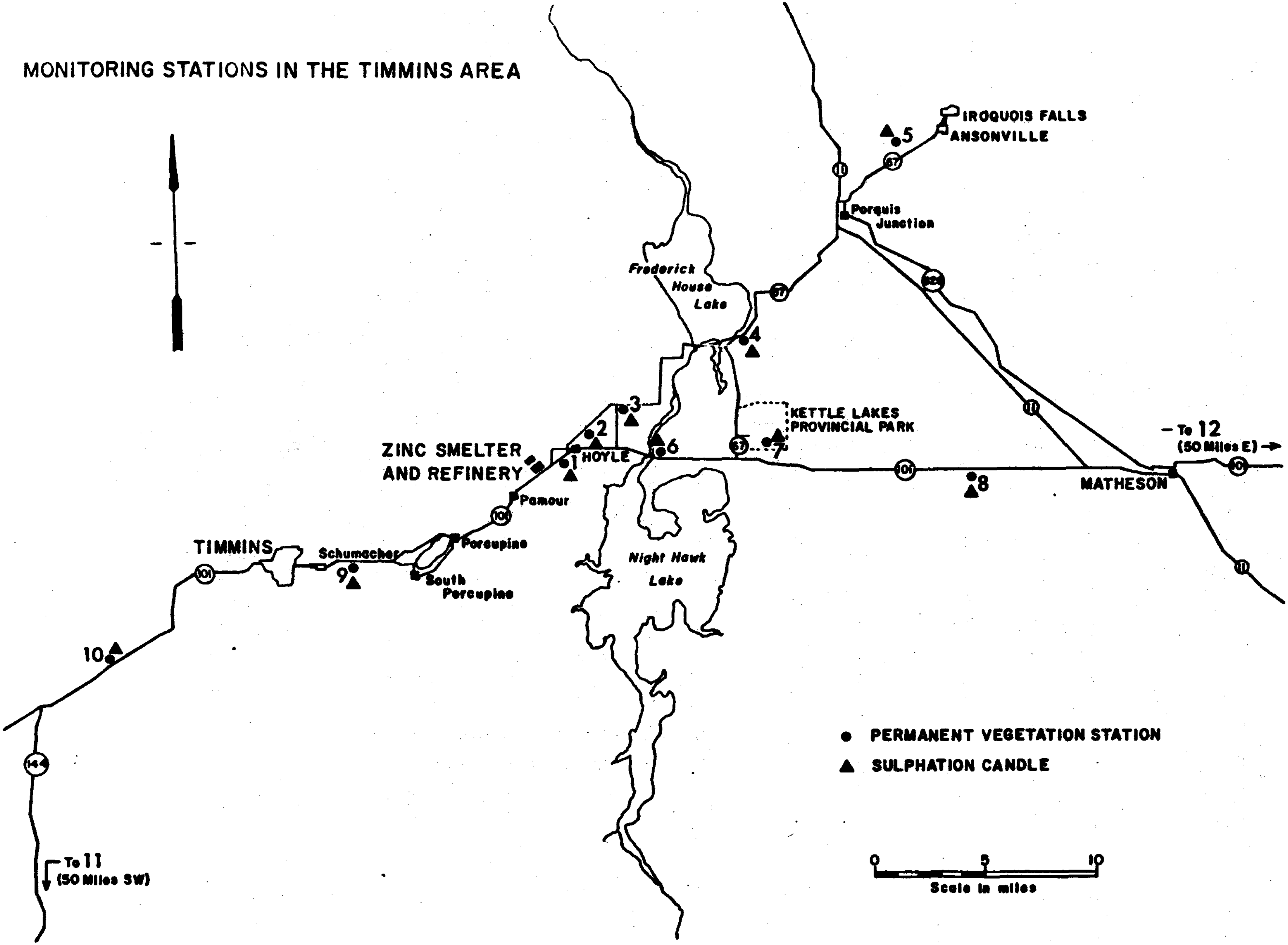
II. Program Outline

During the 1970 growing season each of these plots was visited only once, since the establishment of such a network was a lengthy project. However, in 1971, and 1972, all twelve plots were inspected in June, July, August, and September.

At the time of the 1970 visit, 20 trembling aspen trees and 10 shrubs (alder, hazel, mountain maple, or choke cherry) were tagged in a 66 ft. x 66 ft. area at each plot. The "crown condition" of the trees was recorded, along with insect or disease injury, in order to establish a history of the vegetation on the plots. These conditions were again noted during each month of the growing seasons in 1971 and 1972. As well, in September of each year, the heights and diameters of the tagged trees were recorded for use in growth studies.

In 1970, at each plot, two 3.3 ft. x 3.3 ft. ground cover vegetation grids were established and the number and species of each type of plant found on these grids were recorded to determine any future fluctuations in plant populations. These grids were re-examined in August 1971 and August 1972.

MONITORING STATIONS IN THE TIMMINS AREA



A program of sampling the vegetation, soil, and water for chemical analysis was initiated in the vicinity of each plot established in 1970. Leaf samples from trembling aspen, white birch, alder (or substitute), white spruce, forage, soil, and water were collected and analyzed for fluoride, total sulphur, arsenic, cadmium, iron, and zinc. In June, July, and August 1971, this program was expanded to include jack pine, white spruce, white birch, trembling aspen, speckled alder, beaked hazel (or substitute), forage, soil, and water, which were analyzed for total sulphur, silver, arsenic, cadmium, copper, iron, lead, and zinc. In 1972, this sampling was repeated in June, July, and August, and the samples were similarly analyzed.

In 1971, a lead peroxide candle, to measure ambient levels of sulphur dioxide, was set out at each of the vegetation plots and these candles were exchanged at monthly intervals throughout the 1971 and 1972 growing seasons. During the winter, the candles are left at each station for the period October until May.

III. Observations:

(a) Vegetation Injury

Since the start-up of the refinery in April 1972, a close surveillance was maintained in that area to locate any injury to vegetation by sulphur dioxide or other emitted contaminants. No chemical injury was observed on the foliage of the vegetation close to, or remote from, the new refinery during the 1972 growing season

Several other pathological conditions were noted during this surveillance program. Frost injury which occurred in June and early July was evident on the foliage of most species for the entire season, throughout the study area.

In June 1971, extensive feeding by the larval stage of the Large Aspen Tortrix (Choristoneura conflictana (Wlk.)) thinned-out the crowns of the trembling aspen at Plot 1,2,3, and 9. However, a second burst of foliage in July returned the affected crowns to their previous status. In June 1972 another severe attack by Large Aspen Tortrix occurred at Plot 1, 2, and 9. Less devastating feeding took place at Plots 3,6, and 7. In 1972 however, due to the cool, damp weather conditions in June and July, the second burst of foliage was not as extensive as that in 1971, and the crowns of the severely injured trees remained sparse for the remainder of the season. Similar infestations in subsequent years may cause reduced growth or permanent injury to the trembling aspen growing in the vicinity of Hoyle.

Several fungi (Septoria musiva; Cytospora chrysosperma; Marssonina populi; and Venturia tremulae) causing leaf spots and twig or stem cankers were found to be associated with balsam poplar and trembling aspen on or around the surveillance plots. Light foliar injury or crown die-back occurred as a result of infection by these organisms.

Spruce budworm (Choristoneura fumiferana (Chem.)) caused only minor injury to balsam fir in the study area.

(b) Tree Crown Condition

In 1970, a total of 360 trees or shrubs were tagged at the 12 surveillance plots and the "crown conditions" were noted at the time. The crown conditions were again recorded in 1971 and 1972. The crown condition classification system employed was one developed by the Canadian Forestry Service for hardwood species in Ontario. A classification gradation from 1A (healthy) to 6B (dead), with several intermediate conditions, allowed for an informative description of the crown condition at the time of surveillance. From 1970 to 1972, seven trees (2%) died and 23 trees (6%) had crown conditions which declined. Therefore 92% of the trees or shrubs either maintained or improved their crown condition.

(c) Growth Studies

Excepting the 30 trees or shrubs noted above, the tagged specimens were in a state of good vigor and expanding growth. Most of the trees showed favorable height increases from 1971 to 1972. Diameter increases ranged from trace to 0.2" for the 1971-72 year. Growth was good at plots 1, 2, 3, 4, 5, 6, and 8, with fair to good increments being recorded at the remainder of the plots.

(d) Plant Population Studies

The recording of the vegetation populations in the two ground cover grids established adjacent to each of the twelve Timmins surveillance plots has been in progress for three growing seasons (1970, 1971, 1972). A minimum of five years data are required before meaningful statistical analysis can be applied to the results in this type of study. However, a preliminary review of the information gathered to date reveals the possible indication of meaningful trends. Table 1 shows the average number of plant species present in each of the 24 grids for 1970, 1971, and 1972. It also shows the total and average number of individuals for these plant types. Some plants are more easily tallied as clumps or patches (taking area covered into consideration) and these have also been listed in addition to the number of individuals.

The most striking feature of these figures is the steady increase over the past three years throughout the Timmins study area in the number of individuals and the number of clumps, while the average number of different kinds of plant species remained steady. To date there are no indications that the opening of the refinery has endangered the plant populations in the area. These grids will be examined in the coming seasons to monitor any fluctuations in the ground flora.

(e) Chemical Analysis Results

Chemical analysis of the samples collected in 1972 had not been completed at the time of writing this report. However, the 1970 and 1971 data have been compiled and subjected to statistical analysis. Tables 2 to 10 show the results of the chemical analyses for vegetation, soil, and water sampled at each of the plots. Table 11 shows the analysis of variance for the various chemicals in vegetation, with respect to species and stations. From Table 11 the following trends are apparent:

(a) For all elements except arsenic, the variance between the species is significantly different at the 5% or 1% level. This indicates that the levels of any given element in a single species are not necessarily comparable to the levels of that element in other species.

(b) In 1970, for the combined vegetation analysis, only the levels of cadmium were significantly different from station to station. However, in 1971, cadmium, copper, iron, lead, and zinc were significantly higher at stations 1 and 2, compared to the remainder.

In 1970 only one soil sample was collected at each of the plots, therefore the metal results could not be subjected to statistical analysis. However an analysis of variance has been calculated for several metals in 1971, when two soil samples were obtained at each plot (Table 12). These results show that for silver, cadmium, copper, iron, lead, and zinc the variance from station to station is highly significant. In general, stations 1, 2, 3, 4, and 6 are significantly higher than 5 and 8, while 7, 9, 10, 11, and 12 are significantly lower than the others. Plot 2 is especially elevated where cadmium, copper, and zinc are concerned.

The results of the chemical analysis of the water samples show that, except for isolated readings, all the values were low and uniform.

The results given above show that for a distance of five miles to the east and 10 miles to the north-east of Hoyle there are elevated levels for several metals in the soil. Also the vegetation at plots 1 and 2 contains higher levels of these same metals.

The 1970 sampling program allowed for only one collection at each plot and the results for all plots appeared similar. The changes from 1970 to 1971 are possibly indicative of a trend. Since only the concentrator was operating in 1970 and 1971, the refinery cannot be included in this discussion. With regard to the emissions from the concentrator, it is felt that there would not be sufficient effluent from this source to account for the levels encountered. Possible explanations for the elevated metal levels near Hoyle would include weathering of parent material and blowing of concentrates from open railroad cars while in storage or transit.

Since cadmium -lead-zinc ores are found in this area, there is a possibility that the soil derived from such parent materials could contain these metals in substantial quantities. Metal concentrations with increasing soil depth studies during the coming growing season will indicate whether these metals are more abundant in the upper layers as a result of particulate deposition, or uniform throughout the upper four to six inches which would be more indicative of a natural source.

Following production of the lead and zinc concentrates, these materials are stored in open railroad cars near highway 101, close to the intersection with highway 610. Also the route of shipment travels close to highway 610 and therefore is adjacent to plots 2, 3, 4, and 5. Preliminary investigations have indicated that concentrates blowing from the open railway cars may be a problem during storage along highway 101. Whether or not blowing concentrates are creating an environmental hazard during transport is still to be investigated.

(f) SO_2 Measurements

Analysis of the lead peroxide candles set out in the Timmins area has shown that both before and after the start-up of the new refinery, only background levels of sulphur dioxide were present in the ambient air. The mean values expressed as mg $SO_3/100\ cm^2/day$ for the periods of January to September 1971; October 1971 to April 1972; and May to September 1972 are presented in Table 13.

The Ontario sulphation criterion for desirable ambient air quality is 0.4 mgm $SO_3/100\ cm^2/day$. All values recorded for the period January 1971 to September 1972 in the Timmins area are considerably below this criterion.

IV. Summary and Conclusions

In 1970 the Phytotoxicology Section of the Air Management Branch initiated a pre-pollution background survey of the environmental situation in the Timmins area where Texas Gulf Sulphur was expected to construct an electrolytic zinc refinery near Hoyle (12 miles northeast of Timmins). In April 1972, the refinery began production, and during the 1972 growing season this new plant operated at a rate of 70 to 90% of the theoretical capacity. The refinery is located adjacent to the ore concentrator which has been operative since November 1966. During

1970, 1971, and 1972, Phytotoxicology personnel conducted an extensive program of environmental analysis and evaluation in the area.

The information gathered to date indicates that within a 20 mile radius of the refinery, the condition of the vegetation (trees, shrubs, and ground flora) is similar to that existing in the control areas (number of species, number of plants, growth rate, crown condition etc.) which are located 50 miles from Hoyle.

The lead peroxide candle survey showed that only background levels of sulphur dioxide were present in the ambient air both before and after the initiation of operations at the refinery. No SO_2 injury to vegetation has been observed in the Hoyle area.

Chemical analysis of the vegetation, soil, and water samples collected at twelve established plots in 1971 shows elevated levels of metals in the soil immediately to the east and northeast of Hoyle. These same metals were elevated also in the vegetation collected at plots 1 and 2, close to the plant. Further work is planned to determine the source of this contamination.

The construction plans of the refinery were approved by the Air Management Branch with the objective of keeping emission rates within the standards set by the Branch in order to prevent adverse effects on vegetation, soil, and water in the vicinity of the refinery.

Close surveillance of the environment in the Timmins area will be continued in the 1973 season to provide the necessary information to evaluate the effect, if any, of the effluents generated by this industrial operation at Hoyle.

V. Acknowledgments

The authors wish to express their thanks to Dr. S. N. Linzon, Chief of the Phytotoxicology Section for his supervision, support, and advice; to Messrs. A. W. Hill and P. J. Temple for their assistance with the compilation of the vegetation data; to Mr. A. C. Rayner and Mr. R. Wills and the staff in the Air Laboratory, Laboratory Branch for chemical analysis of the vegetation, soil, and water samples, as well as the lead peroxide candles; to Mr. B. Chai for the statistical analysis of the chemical data; and to Mrs. Janet Springer for secretarial assistance. Without the co-ordinated effort of all of these people, the presentation of this report would not have been possible.

APPENDIX

Table 1: Summary of the Ground Flora Populations in the Grids adjacent to the Timmins Vegetation Plots in 1970, 1971, and 1972.

	1970	1971	1972
Average No. of plant Species per Grid	12	13	13
Total No. of Individual Plants on 24 Grids	3326	4112	4152
Average No. of Individual Plants per Grid	139	171	173
Total No. of Clumps of Plants on 24 Grids	573	632	813
Average No. of Clumps of Plants per Grid	24	26	34

Table 2: Concentrations of the Various Chemical Elements in Trembling Aspen collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and three (1971) monthly collections).

Trembling Aspen
(washed)

Chemicals

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.22	.23	-	0.6	0.5	1.3	.50	1.3	-	13.1	67	82	-	6	280	314
2	2 m. NE	.22	.23	-	0.6	0.5	0.8	1.06	2.4	-	14.2	130	97	-	10	300	507
3	5 m. NE	.22	.21	-	0.4	0.7	0.5	.34	0.8	-	9.2	71	52	-	4	270	186
4	10 m. NE	.23	.29	-	0.6	0.5	0.6	.59	1.2	-	9.2	33	50	-	6	265	240
5	20 m. NE	.30	.22	-	0.3	0.5	1.0	.45	0.9	-	9.9	54	62	-	4	140	146
6	5 m. E	.16	.20	-	0.4	0.5	0.9	.74	2.1	-	8.4	46	69	-	8	266	281
7	10 m. E	.27	.21	-	0.3	0.5	0.8	.10	0.3	-	7.0	59	55	-	4	152	132
8	20 m. E	.20	.25	-	0.3	1.4	1.2	.70	0.8	-	8.6	51	39	-	5	250	152
9	10 m. SW	.21	.26	-	0.4	0.6	0.9	.68	0.9	-	8.0	38	60	-	5	310	227
10	20 m. SW	.24	.25	-	0.4	0.5	1.3	.16	1.0	-	8.9	46	48	-	6	220	254
11	50 m. SW	.24	.21	-	0.6	0.6	1.0	.12	0.8	-	7.8	47	55	-	6	168	151
12	50 m. SE	.24	.23	-	0.3	0.5	0.8	.32	1.5	-	8.6	38	62	-	4	152	146
Max.		.30	.36	-	0.6	1.4	1.3	1.06	2.4	-	14.2	130	97	-	10	310	507
Min.		.16	.16	-	0.3	0.5	0.5	.50	0.3	-	7.0	33	39	-	2	140	132
Mean		.23	.23	-	0.4	0.6	0.9	.48	1.2	-	9.4	57	61	-	6	231	228

* Distance and Direction from Hoyle
- Plots 11 and 12 are control plots

Table 3: Concentrations of the Various Chemical Elements in White Birch collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and three (1971) monthly collections).

Chemicals

White Birch
(washed)

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.14	.20	-	0.5	0.6	1.1	1.01	1.1	-	20.2	33	162	-	9	300	457
2	2 m. NE	.13	.12	-	0.4	0.6	0.9	1.40	1.3	-	5.6	87	141	-	9	820	990
3	5 m. NE	.21	.20	-	0.2	0.5	0.7	.57	0.5	-	5.5	12	61	-	4	200	95
4	10 m. NE	.13	.14	-	0.5	0.5	1.3	.12	0.9	-	9.9	36	48	-	4	200	228
5	20 m. NE	.20	.18	-	0.6	0.5	1.2	.54	0.9	-	8.7	37	60	-	6	420	367
6	5 m. E	.16	.15	-	0.2	0.5	1.1	.24	0.7	-	5.2	72	80	-	6	150	185
7	10 m. E	.13	.19	-	0.3	0.5	1.0	.76	0.7	-	5.8	13	39	-	5	240	172
8	20 m. E	.21	.20	-	0.4	0.5	0.7	.80	0.6	-	8.3	34	77	-	5	325	218
9	10 m. SW	.21	.19	-	0.4	0.6	1.6	.68	1.1	-	9.6	38	76	-	6	310	179
10	20 m. SW	.19	.14	-	0.3	0.6	1.2	.62	1.3	-	6.5	47	52	-	4	340	309
11	50 m. SW	.22	.17	-	0.2	0.6	1.1	.24	0.6	-	8.2	78	57	-	5	75	152
12	50 m. SE	.19	.23	-	0.4	0.6	1.2	.18	1.3	-	9.9	38	78	-	6	24	276
Max.		.22	.23	-	0.5	0.6	1.6	1.40	1.3	-	20.2	87	162	-	9	820	990
Min.		.13	.12	-	0.2	0.5	1.1	.12	0.5	-	5.2	12	39	-	4	24	95
Mean		.18	.18	-	0.4	0.6	0.7	.60	0.9	-	8.6	44	78	-	6	284	302

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

Table 4: Concentrations of the Various Chemical Elements in Speckled Alder collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and three (1971) monthly collections).

Speckled Alder
(Washed)

Chemicals

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.14	.19	-	0.5	0.5	0.8	.20	0.5	-	21.4	10	97	-	7	13	103
2	2 m. NE	.22	.17	-	0.6	0.5	1.5	.28	0.5	-	17.2	95	107	-	5	100	119
3	5 m. NE	.22	.21	-	0.2	0.6	1.2	.29	0.4	-	9.7	78	87	-	4	33	43
4	10 m. NE	.21	.20	-	0.4	0.9	1.2	.11	0.6	-	10.9	62	62	-	6	39	51
5	20 m. NE	.22	.20	-	0.3	0.5	1.3	.29	0.6	-	15.6	60	67	-	5	44	35
6	5 m. E	.22	.19	-	0.3	0.5	1.0	.27	0.4	-	8.6	25	85	-	10	54	32
7	10 m. E	.21	.20	-	0.2	1.4	0.8	.25	0.3	-	5.9	52	114	-	4	27	26
8	20 m. E	.20	-	-	-	0.5	-	.10	-	-	-	57	-	-	-	45	-
9	10 m. SW	.24	.20	-	0.4	0.5	2.3	.26	0.5	-	9.8	73	57	-	4	45	36
10	20 m. SW	.23	.23	-	0.5	0.5	0.7	.20	0.5	-	5.7	66	47	-	5	70	39
11	50 m. SW	.19	-	-	-	0.9	-	.20	-	-	-	57	-	-	-	33	-
12	50 m. SE	.18	.23	-	0.3	0.5	1.2	.20	0.3	-	6.9	10	80	-	5	120	70
Max.		.24	.23	-	0.6	1.4	2.3	.91	0.6	-	21.4	95	107	-	10	120	119
Min.		.14	.17	-	0.2	0.5	0.7	.10	0.3	-	5.7	10	47	-	4	13	26
Mean		.21	.20	-	0.4	0.7	1.2	.28	0.4	-	11.2	54	80	-	6	52	55

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

Table 5: Concentrations of the Various Chemical Elements in Current Year White Spruce Needles collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and three (1971) monthly collections.

White Spruce Needles
(Current Needles washed)

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.07	.09	-	.03	0.7	0.9	.16	0.2	-	7.8	35	58	-	4	72	83
2	2 m. NE	.09	.14	-	.04	0.5	1.4	.18	0.5	-	7.1	29	35	-	7	83	69
3	5 m. NE	.10	.10	-	.02	0.5	0.9	.15	0.3	-	3.5	21	17	-	3	60	48
4	10 m. NE	.12	.09	-	.03	0.5	1.3	.16	0.3	-	12.2	18	71	-	4	66	99
5	20 m. NE	.08	.11	-	.02	0.5	1.6	.30	0.3	-	5.1	30	21	-	3	54	57
6	5 m. E	.11	.09	-	.02	1.1	0.7	.15	0.2	-	4.8	34	25	-	3	68	60
7	10 m. E	.06	.08	-	.02	0.5	0.8	.14	0.3	-	3.5	20	32	-	4	50	37
8	20 m. E	.07	.10	-	.03	0.5	1.0	.10	0.2	-	4.3	25	39	-	3	66	46
9	10 m. SW	.11	.09	-	.03	0.7	1.1	.10	0.3	-	4.5	27	19	-	3	53	60
10	20 m. SW	.07	.10	-	.02	0.5	1.2	.20	0.3	-	4.3	18	32	-	3	60	55
11	50 m. SW	.09	.10	-	.02	0.5	0.9	.16	0.3	-	5.3	30	20	-	3	68	56
12	50 m. SE	.08	.12	-	.02	0.5	1.1	.10	0.3	-	5.7	10	27	-	2	16	43
Max.		.12	.14	-	.04	1.1	1.6	.30	0.5	-	12.2	35	58	-	7	83	99
Min.		.06	.08	-	.02	0.5	0.7	.10	0.2	-	3.5	10	19	-	2	16	37
Mean		.09	.10	-	.03	0.6	1.1	.16	0.3	-	5.7	25	33	-	4	60	59

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

Table 6 : Concentrations of the Various Chemical Elements in White Spruce Needles (Current and one year-old) collected at the Timmins Surveillance Plots during the 1971 growing season (Average of three monthly collections).

White Spruce (washed)
(current and one year-old needles)

Chemicals

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.
1	1 m. NE	.09	.08	0.3	0.4	0.9	0.8	0.2	0.4	7.8	9.1	58	79	4	5	83	87
2	2 m. NE	.14	.07	0.4	0.4	1.4	0.5	0.5	0.5	7.1	4.4	35	78	7	4	69	118
3	5 m. NE	.10	.08	0.2	0.2	0.9	0.9	0.3	0.4	3.5	2.5	17	25	3	4	48	72
4	10 m. NE	.09	.10	0.3	0.3	1.3	1.9	0.3	0.5	12.2	18.1	71	141	4	6	99	151
5	20 m. NE	.11	.06	0.2	0.2	1.6	1.4	0.3	0.5	5.1	1.5	21	22	3	3	57	58
6	5 m. E	.09	.09	0.2	0.4	0.7	1.1	0.2	0.4	4.8	2.0	25	23	3	5	60	93
7	10 m. E	.08	.08	0.2	0.3	0.8	0.7	0.3	0.3	3.5	1.9	32	33	4	4	37	51
8	20 m. E	.10	.08	0.3	0.3	1.0	0.9	0.2	0.4	4.3	2.4	39	27	3	3	46	83
9	10 m. SW	.09	.08	0.3	0.4	1.1	1.0	0.3	0.6	4.5	2.6	19	21	3	6	60	99
10	20 m. SW	.10	.06	0.2	0.2	1.2	1.3	0.3	0.4	4.2	1.4	32	30	3	7	55	74
11	50 m. SW	.10	.06	0.2	0.3	0.9	0.9	0.3	0.3	5.3	2.2	20	35	3	4	56	39
12	50 m. SE	.12	.11	0.2	0.2	1.1	0.9	0.3	0.3	5.7	3.7	27	30	2	3	43	55
Max.		.14	.11	0.4	0.4	1.6	1.9	0.5	0.5	12.2	18.1	58	141	7	7	99	151
Min.		.08	.06	0.2	0.2	0.7	0.5	0.3	0.3	3.5	1.4	19	21	2	3	37	39
Mean		.10	.08	0.3	0.3	1.1	1.0	0.4	0.4	5.7	4.3	33	45	4	5	59	82

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

Table 7: Concentrations of the Various Chemical Elements in Jack Pine Needles. (Current and One year-old) collected at the Timmins Surveillance Plots during the 1971 growing season (Average of two monthly collections).

Jack Pine (Current and One year-old needles)
(washed)

Chemicals

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.	Cur.	1-Yr.
1	1 m. NE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2 m. NE	.12	.09	0.2	0.3	0.8	1.0	0.4	0.4	6.0	8.6	48	-	4	6	68	99
3	5 m. NE	.09	.07	0.2	0.2	0.8	0.8	0.5	0.3	5.9	2.9	55	48	4	6	68	57
4	10 m. NE	.10	.08	0.3	0.3	1.0	1.0	0.3	0.3	4.8	3.2	40	55	3	8	58	112
5	20 m. NE	.09	.08	0.2	0.2	1.1	1.2	0.4	0.4	4.0	3.2	31	70	3	8	67	66
6	5 m. E	.08	.08	0.2	0.3	1.1	1.1	0.2	0.2	4.1	4.8	33	112	5	23	46	56
7	10 m. E	.09	.09	0.2	0.2	1.1	0.8	0.2	0.3	3.9	3.1	44	86	2	3	52	56
8	20 m. E	.11	.09	0.2	0.2	1.1	0.7	0.2	0.2	3.9	2.0	29	38	5	7	53	112
9	10 m. SW	.09	.08	0.7	0.6	1.3	1.8	0.5	0.5	3.6	3.9	50	87	11	44	54	76
10	20 m. SW	.10	.08	0.2	0.2	1.0	0.7	0.4	0.3	3.6	2.0	21	43	4	4	52	46
11	50 m. SW	.09	.09	0.2	0.2	1.3	1.0	0.3	0.3	2.7	2.2	28	66	4	5	40	29
12	50 m. SE	.10	.08	0.2	0.2	0.7	0.9	0.2	0.2	3.8	3.4	31	46	3	5	62	76
Max.		.12	.09	0.7	0.7	1.3	1.8	0.5	0.5	6.0	8.6	55	112	5	44	68	112
Min.		.09	.07	0.2	0.2	0.7	0.7	0.2	0.2	2.7	2.0	28	38	3	3	40	29
Mean		.08	.08	0.2	0.2	0.9	0.9	0.3	0.3	3.9	3.3	35	59	4	13	52	65

* Distance and Direction from Hoyle
- Plots 11 and 12 are control plots

1971 Ag based on one monthly collection

Table 8: Concentrations of the Various Chemical Elements in Forage (not washed) collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and three (1971) monthly collections).

Forage
(not washed)

Chemicals

Plot #	*Location	ToS	%	Ag	ppm	As	ppm	Cd	ppm	Cu	ppm	Fe	ppm	Pb	ppm	Zn	ppm
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.14	.20	-	0.3	0.5	1.5	.18	0.3	-	4.2	29	55	-	3	40	28
2	2 m. NE	.25	.18	-	0.3	1.9	1.0	.12	0.3	-	8.2	50	87	-	3	40	78
3	5 m. NE	.14	.19	-	0.3	0.5	1.8	.20	0.3	-	5.7	43	57	-	3	27	9
4	10 m. NE	.16	.22	-	0.3	0.5	0.8	.10	0.6	-	4.1	39	59	-	3	26	63
5	20 m. NE	.10	.18	-	0.3	0.5	1.4	.10	0.2	-	5.1	14	57	-	2	16	21
6	5 m. E	.14	.16	-	0.2	0.5	0.8	.20	0.3	-	3.5	44	64	-	3	30	45
7	10 m. E	.10	.28	-	0.3	0.5	0.8	.15	0.3	-	7.6	87	71	-	3	26	31
8	20 m. E	.20	.17	-	0.4	0.9	0.9	.37	0.3	-	7.6	48	50	-	3	35	32
9	10 m. SW	.17	.20	-	0.3	0.9	1.3	.15	0.4	-	5.9	45	48	-	2	57	60
10	20 m. SW	.15	.16	-	0.3	0.6	0.8	.10	0.3	-	2.7	32	41	-	4	42	35
11	50 m. SW	.14	.16	-	0.3	0.5	0.7	.15	0.4	-	5.7	49	44	-	4	17	26
12	50 m. SE	.22	.22	-	0.3	0.5	1.6	.12	0.2	-	8.8	47	55	-	3	28	22
Max.		.25	.28	-	0.4	1.9	1.8	.37	0.6	-	8.8	87	87	-	4	57	78
Min.		.10	.16	-	0.2	0.5	0.8	.10	0.2	-	2.7	14	41	-	2	16	9
Mean		.16	.19	-	0.3	0.7	1.1	.16	0.3	-	5.8	44	57	-	3	32	38

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

Table 9: Concentrations of the Various Chemical Elements in the Soil (0-4") collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and two (1971) monthly collections).

Soil
(0-4")

Chemicals

Plot #	*Location	ToS %		Ag ppm		As ppm		Cd ppm		Cu ppm		Fe %		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	.10	.04	-	1.0	4.4	6.8	3	2.2	-	56	2.32	3.53	-	37	280	238
2	2 m. NE	.20	.18	-	0.9	2.8	6.6	4	6.0	-	289	0.72	2.16	-	49	51	775
3	5 m. NE	.05	.04	-	0.8	3.6	4.0	3	1.9	-	17	1.65	1.15	-	17	42	81
4	10 m. NE	.01	.11	-	0.9	2.0	5.4	3	2.3	-	27	2.37	3.25	-	31	100	234
5	20 m. NE	.04	.04	-	0.7	5.8	3.8	3	0.7	-	19	2.50	2.42	-	21	71	221
6	5 m. E	.03	.05	-	1.0	5.2	6.8	3	2.2	-	31	4.15	4.23	-	37	132	201
7	10 m. E	.02	.04	-	0.5	2.0	1.6	3	0.7	-	4	0.72	0.48	-	8	39	61
8	20 m. E	.15	.15	-	0.5	2.8	3.6	3	1.8	-	14	1.20	1.23	-	22	105	103
9	10 m. SW	.04	.03	-	0.5	5.6	1.8	3	0.5	-	9	0.78	0.92	-	14	36	40
10	20 m. SW	.01	.05	-	0.5	2.0	3.4	3	0.8	-	4	0.57	0.64	-	12	10	28
11	50 m. SW	.02	.05	-	0.5	2.0	1.6	3	0.5	-	6	0.65	0.56	-	12	24	38
12	50 m. SE	.005	.04	-	0.5	2.0	3.6	3	0.8	-	6	0.42	0.72	-	13	11	28
Max.		.20	.18	-	1.0	4.4	6.8	4	6.0	-	289	4.15	4.23	-	49	280	775
Min.		.005	.03	-	0.5	2.0	1.6	3	0.5	-	4	0.42	0.56	-	8	10	28
Mean		.06	.07	-	0.7	2.6	4.1	3	1.7	-	40	1.51	1.77	-	23	75	171

For Cd (1970) a value of 3 means "less than 3".
1971 As based on one monthly collection

* Distance and Direction from Hoyle
- Plots 11 and 12 are control plots

Table 10: Concentrations of the Various Chemical Elements in Water collected at the Timmins Surveillance Plots during the 1970 and 1971 growing seasons (Average of one (1970) and two (1971) monthly collections).

Water

Chemicals

Plot #	*Location	SO_4 meq/l	ToS ppm	Ag ppm		As ppb		Cd ppm		Cu ppm		Fe ppm		Pb ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
1	1 m. NE	-	15.3	-	.003	-	8.1	-	.003	-	.007	-	0.23	-	0.03	-	0.05
2	2 m. NE	-	-	-	.003	-	-	-	-	-	-	-	-	-	-	-	-
3	5 m. NE	-	2.3	-	.003	-	2.5	-	.003	-	.007	-	0.71	-	0.03	-	0.14
4	10 m. NE	.32	1.3	-	.003	10	1.3	.02	.003	-	.011	0.0	0.33	-	0.03	.014	0.89
5	20 m. NE	-	2.1	-	.003	-	1.0	-	.003	-	.006	-	0.05	-	0.03	-	0.31
6	5 m. E	.39	3.3	-	.003	9	1.9	.02	.003	-	.001	0.2	1.49	-	0.03	.018	0.04
7	10 m. E	.14	2.2	-	.003	5	1.3	.02	.003	-	.006	0.0	0.14	-	0.03	.009	0.06
8	20 m. E	-	2.2	-	.003	-	2.5	-	.003	-	.026	-	0.42	-	0.03	-	0.18
9	10 m. SW	.38	46.0	-	.003	16	18.4	.02	.003	-	.019	0.2	0.15	-	0.03	.02	0.14
10	20 m. SW	.22	2.3	-	.003	8	2.1	.02	.003	-	.012	0.1	0.75	-	0.03	.001	0.23
11	50 m. SW	-	1.8	-	.003	-	1.3	-	.003	-	.011	-	0.09	-	0.03	-	0.12
12	50 m. SE	-	2.6	-	.003	-	3.1	-	.003	-	.006	-	0.70	-	0.03	-	0.12
												0.2					
Max.		.39	46.0	-	.003	16	18.4	.02	.003	-	.026	0.2	1.49	-	0.03	.02	0.89
Min.		.14	1.3	-	.003	5	1.0	.02	.003	-	.006	0.0	0.05	-	0.03	.001	0.04
Mean		.27	7.4	-	.003	9	4.0	.02	.003	-	.010	0.1	0.46	-	0.03	.012	0.21

* Distance and Direction from Hoyle

- Plots 11 and 12 are control plots

1971 As based on one monthly collection
For Cd (1970) a value of 0.02 means "less than 0.02"
For Ag and Cd (1971) a value of 0.003 means "less than 0.003"
For Pb (1971) a value of 0.03 means "less than 0.03"

Table 11: Summary of Analysis of Variance (F - Values) For Different Chemicals in Vegetation in Timmins (1970 and 1971)

Chemical	Total Sulphur		Silver		Arsenic		Cadmium		Copper		Iron		Lead		Zinc	
Year	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Sources of **Variation**																
Species	35.0**	41.70**		6.05**	0.50	1.23	23.67**	31.32**		3.47*	5.35**	6.00**		16.51**	6.91**	35.86**
Stations	1.0	0.96		1.48	0.58	0.95	3.68*	2.23*		3.35**	1.79	2.52**		2.32*	0.56	4.88**

* - significant at 5% level

** - significant at 1% level

Table 12 : Summary of Analysis of Variance (F - values) for several metals in Soil in Timmins (1971)

Chemical Source of Variance	Silver	Cadmium	Copper	Iron	Lead	Zinc
Station	13.11**	8.35**	6.04**	6.19**	5.69**	5.15**

** - Significant at 1% level

Table 13: **Air Quality Survey - Timmins**

Plot #	Distance and Direction from Hoyle	Mean Value (mg SO_3/100 cm^2/day) Jan. - Sept. 1971	Oct. 1971 - April 1972	May - Sept. 1972
1	1 m. NE	.05	.09	.07
2	2 m. NE	.03	.07	.03
3	5 m. NE	.03	.05	.01
4	10 m. NE	.07	.12	.05
5	20 m. NE	.04	.07	.02
6	5 m. E	.05	.08	.03
7	10 m. E	.04	.08	.03
8	20 m. E	.08	.12	.05
9	10 m. SW	.06	.08	.03
10	20 m. SW	.03	.04	.01
11	50 m. SW	.06	.12	.03
12	50 m. SE	.04	.07	.04